Ocean Acoustics and Signal Processing for Robust Detection and Estimation

Zoi-Heleni Michalopoulou
Department of Mathematical Sciences
New Jersey Institute of Technology
Newark, NJ 07102
phone: (973) 596 8395 fax: (973) 596 6467 email: elmich@m.njit.edu
http://www.math.njit.edu/~elmich
Award Number: N000149710600

LONG TERM GOALS

The long-term goal of this project is to develop fast and accurate methods for geoacoustic inversion, localization, and detection by combining the physics of sound propagation in the ocean and principles of signal processing.

OBJECTIVES

1. Develop robust, computationally efficient methods for spatially and temporally coherent inversion.
2. Develop methods for passive localization and inversion of environmental parameters that select features of propagation that are essential to model for accurate inversion.

APPROACH

The investigator's work on coherent matched-field processing has demonstrated the benefit of that approach over conventional, incoherent matched-field processing when the source spectrum is well-known. The benefit comes at the cost of substantial computational overhead. Preliminary work with data from the SWellEX-96 experiment showed that matching estimates of the ocean impulse response to replica impulse responses is a coherent matched-field approach, significantly more efficient than traditional coherent time-series matching but with comparable results. The investigator identified procedures to extract the ocean impulse response from recorded data for use in matched-impulse response processing.

The investigator also studied the possibility of feature extraction from (synthetic) received time-series for the development of algorithms for fast, accurate localization and inversion for environmental parameters. Some preliminary results were obtained by performing multipath arrival identification for source localization and multipath amplitude estimation for sediment property inversion.

RESULTS

The quality of the estimate of the ocean impulse response was found to depend on the source characteristics (frequency content and modulation) and the methods used for the deconvolution of the impulse response from the received time-series. In the presence of *lfm* sources a simple crosscorrelation was found adequate for impulse response extraction. For *hfm* source sequences, Wiener deconvolution with singular value decomposition was preferable for robust impulse response

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Ocean Acoustics and Signal Processing for Robust Detection and Estimation**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **New Jersey Institute of Technology,Department of Mathematical Sciences,Newark,NJ,07102**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

extraction. It was concluded that the nature of the source sequence should dictate the method to use for optimal impulse response extraction.

The impulse response estimation methods were tested on the SWellEX-96 data. Once estimates of the ocean impulse response were extracted, they were employed in *matched-impulse response processing*. Source localization was performed successfully with 1 km data using this approach [1]. For the same range, properties of the seafloor sediment were also inverted for and the estimated values were found compatible with results obtained from other inversion methods applied to data from the same site [2]. The incoherent Bartlett processor gave very similar estimates to the matched-impulse response processor for the 1 km data.

Inversion using the same approaches was also performed using further range (8.5 km) data from the SWellEX-96 experiment. The matched-impulse-response-processing scheme was applied under the (erroneous) assumption of range independence. Source location results obtained with this method were very good (Figure 1 (a)); results from the incoherent broadband Bartlett processor under the same assumption of range independence were highly ambiguous (Figure 1 (b)).

The feature selection process was very successful with synthetic data where time arrivals were estimated from received time series using correlation calculations [2]. The time arrivals of a few paths were selected and the relative path arrivals at the same phone and across separated phones were used for source localization. Mostly short-range cases were examined. The paths of choice were the direct and first surface bounce, which do not interact with the ocean bottom. Therefore, lack of accurate bathymetry information and/or modeling does not affect the estimation results. The quality of the results depended on the uncertainty in the time arrival measurements and the number and position of receiving phones. The method developed in this project extended the approach presented in [4], where inversion was performed using a linearized relationship between source and receiver locations and direct time arrivals.

IMPACT

The matched-impulse response processing method requires only a short implementation time and can be used efficiently as a robust alternative to incoherent matched-field processing especially in active problems where the source sequence is well-known. The data filtering implied by the feature (time arrival, amplitude) selection from received time-series is expected to simplify passive, broadband matched-field inversion without a penalty in the quality of the estimates. It is also expected to lead to successful, fast tracking algorithms that will estimate change of position by measuring the changes in the selected features. Multipath feature selection is suitable to high-frequency broadband data and can, therefore, be applied to the localization and tracking of marine mammals producing short, high-energy vocalizations such as clicks.

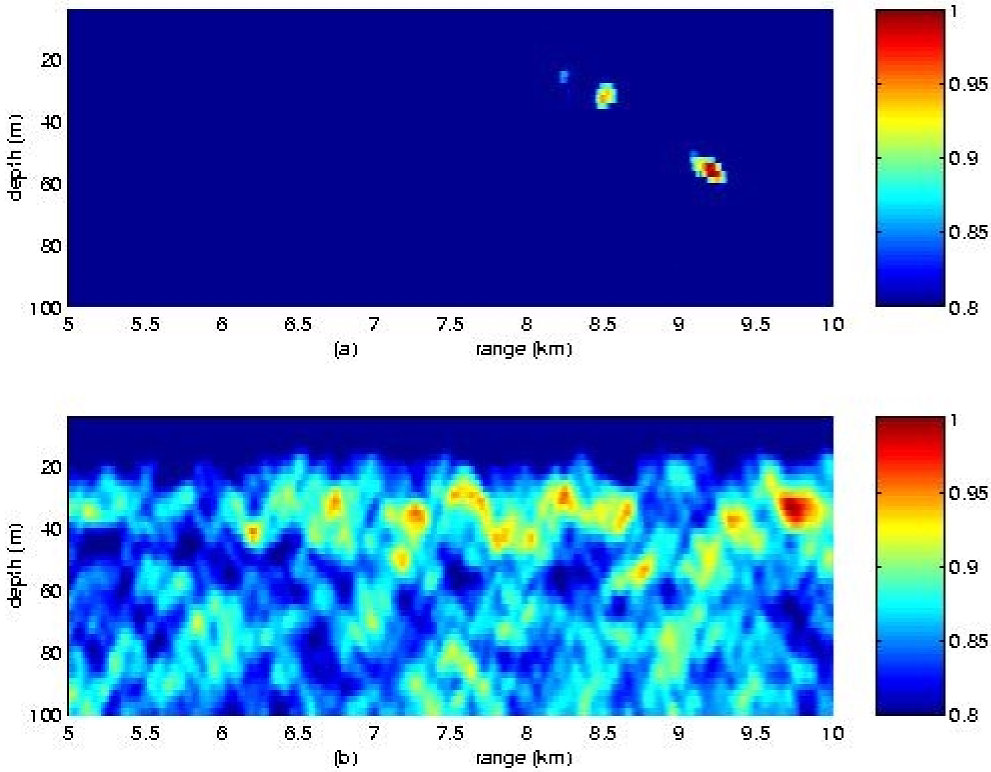

Fig. 1: Ambiguity surfaces computed with (a) matched impulse response processing and (b) incoherent broadband Bartlett processing of SWellEX-96 data. The matched-impulse response processor gave an estimate of 56 m and 9.2 km for range and depth. The correct source location was approximately 56 m in depth and 8.6 km in range. The error in bathymetry modeling appears to be the reason for the range shift in the matched-impulse response processing results. The incoherent Bartlett processor did not identify the source location correctly.

REFERENCES

1. Zoi-Heleni Michalopoulou, *Matched-impulse response processing for shallow water localization and geoacoustic inversion*, submitted to the Journal of the Acoustical Society of America.
2. Paul A. Baxley, *Matched field geoacoustic parameter inversion using horizontal line arrays*, in Fourth International Conference on Theoretical and Computational Acoustics, Trieste, Italy, May 1999.
3. Xiaoqun Ma and Zoi-Heleni Michalopoulou, *Matched time arrival processing for efficient inversion in underwater acoustics*, Proceedings of Oceans 99, pp. 1577-1580, Seattle Washington, September 1999.
4. S. E. Dosso, M. R. Fallat, B. J. Sotirin and J. L. Newton, *Array element localization for horizontal arrays via Occam's inversion*, Journal of the Acoustical Society of America, vol. 104, no. 2, pp. 846-859, August 1998.

PUBLICATIONS

Zoi-Heleni Michalopoulou, *Matched impulse response processing for shallow water localization and geoacoustic inversion*, submitted to the Journal of the Acoustical Society of America.

Zoi-Heleni Michalopoulou, *Active source detection in a dispersive multiple reflection environment*, Proceedings of ICASSP 99, Phoenix, Arizona, March 1999.

Zoi-Heleni Michalopoulou and Michele Picarelli, *Coherent and incoherent shallow water matched field inversion*, Journal of the Acoustical Society of America, vol. 104, no. 3, part 2, pp. 1739.

Zoi-Heleni Michalopoulou and Xiaoqun Ma, *Impulse response estimation for inversion and source localization*, First Workshop on Inverse Problems, Herakleion, Crete, May 1999.

Xiaoqun Ma and Zoi-Heleni Michalopoulou, *A linearization approach to source localization in an uncertain environment,* SIAM Annual Meeting, Atlanta, Georgia, May 1999.

Xiaoqun Ma and Zoi-Heleni Michalopoulou*, Matched time arrival processing for efficient inversion in underwater acoustics*, Proceedings of Oceans 99, Seattle, Washington, September 1999.

Zoi-Heleni Michalopoulou, *Marine mammal signal processing: accounting for the underwater channel effects*, IEEE Workshop on Underwater Acoustic Signal Processing, University of Rhode Island, October 1999.